Cochlear implants are devices that are used to artificially excite nerves with patterns of stimulation that convey speech information and environmental sounds when a person’s inner ear has been destroyed by disease or not developed at birth. In this situation they cannot benefit from the amplification of sound with a hearing aid.

The inner ear is a small fluid-filled shell-shaped chamber which houses a membrane that vibrates in response to sound. The hairs of these cells transduce mechanical vibrations into electrical signals which excite auditory nerve fibres leading to the brain. The membrane also acts as a filter so that high frequency sounds produce a maximal disturbance near the round window whereas low frequency sounds produce a maximum more distantly at the apex. Coding of frequency may occur in one of two ways, firstly on a temporal code, the brain deciphering the signal on the basis of timing of nerve action potentials, or secondly on a place basis depending on the site of stimulation within the brain. For place coding the brain cells are arranged so that a frequency scale of units’ responses occurs.

The challenge facing cochlear implants some years ago was how to adequately simulate the coding of frequency and intensity by a small number of electrodes when there is normally a very complex arrangement of hair cells and nerve fibres. The other important challenge was how to break speech down into appropriate signals to be coded by the artificial stimuli.

As a result of research in Melbourne we developed a system for analysing speech that enabled our initial patients to understand running speech. The initial speech processing strategy extracted one important parameter of speech necessary for intelligibility and presented this on the basis of place coding within the cochlea and an appropriate rate of stimulation to convey voicing. The prototype device worn by the first patient is shown in Figure 1.

Subsequently, this strategy was implemented as a wearable system developed at the University of Melbourne. How the system operates is illustrated diagrammatically in Figure 2. Sound waves are picked up by a microphone and converted into electrical signals. These are sent to a speech processor which is worn by the patient. This decodes the signal, selects out the appropriate features, produces a code and maps this for the particular requirements of the individual in terms of threshold and dynamic range of stimulation. This signal is then transmitted through the intact skin by radio waves to an implanted receiver-stimulator section which in turn decodes the signal and presents patterns of electrical stimuli to different electrodes within the inner ear. Power to operate the device is also transmitted through the intact skin so that no implanted batteries are needed. This prototype speech processing strategy and speech processor (Figure 2) was developed industrially by the Australian Biomedical firm Nucleus, also the holding company for Telemedics who had pioneered pacemaking.
A cochlear implant is a device that helps people who are deaf or hard of hearing to hear. It works by sending sound to the inner ear through an electrode array that is inserted into the cochlea. The device is surgically implanted and is capable of reconstructing sound patterns that can be perceived by the user.

Cochlear implants are used on children after initial evaluation. Children, however, present special problems (it needed to be considered before undertaking the procedure). First, when they are born, deaf or lose hearing early in their anterior pathways do not develop normally. This response to sound is very important in maintaining certain essential contacts between the neurons in the auditory pathways. These contacts are not made during the early developmental stage in the auditory system. Furthermore, children who have not developed speech by the time they are four are not able to adequately pronounce speech sounds and therefore, language development suffers as well. Few deaf children ever reach the normal level for age; competence in spoken or written English language. Another difficulty that has to be faced when considering children for cochlear implants is their educational placement. Some children with profound hearing loss may be taught in an auditory-oral, or auditory-verbal environment or in which they are encouraged to use residual hearing they might have acquired while wearing a hearing aid and learn to combine that with reading a sign language or speech.

At the same time they are given training in the production of speech sounds. On the other hand, other children are taught to combine this training with a series of signs that help emphasize meaning, and these are grammatically appropriate for the English language. A third option adopted by some parents is to teach their children to learn speech language of the deaf, called Auslan in Australia. This is a system of signs that convey meaning, which is not consistent with the grammar of the English language and does not emphasize combined use with lip reading. It is a system of signs that need to be learned and understood by the person communicating with the deaf child. As cochlear implants provide audible stimulation it is important that the child has learned in auditory-oral, auditory-verbal or a total communication environment with emphasis on auditory stimulation rather than communication from a sign language of the deaf background. Certainly they should not be educated with sign language of the deaf if hearing has been restored.

Another issue of importance with children is the head size and head growth. It is important to make sure that head growth is infrequent to later childhood would not result in the electrode being pulled out of the inner ear, and secondly that the implant procedure itself did not interfere with head growth. In addition, infants and young children are very prone to middle ear infection and it was seen as important to make sure that the implant procedure and healing around the entry point into the inner ear would not lead to a pathway for infection to reach trick to the inner ear, leading to labyrinthitis and possibly even meningitis. These bony areas were studied at the University of Melbourne over more than ten years, and more recently, as part of a five-year U.S. National Institutes of Health's contract. It studies it was shown that head growth, although significant, so not lead to any difficulties providing there was adequate redundancy in the lead wire allowed between the point of exit in the inner ear and the package and that this redundancy when an appropriate configuration that would not be bound in the tissue. Also the sealing around the electrode track as entered.
that ear was found to be adequate, particularly if this was
covered with a fibrous tissue autograft.

Finally, there are ethical issues of relevance in the case of children
and these concerns the rights of patients to act on behalf of their
children. Most profoundly deaf children are born into the families
of hearing parents and these parents in general wish their children
to be given the opportunity to hear and participate in the hearing
world, rather than to be made to learn sign language of the deaf.
The most preferable option is to provide a cochlear implant at an
earlier age, while the brain is still maturing so that they have a better
opportunity of learning to understand speech. Later on they will
have the choice of learning a sign language of the deaf if they so
desire. They cannot however learn to hear speech if sign language
of the deaf is taught in the early years and an implant is offered at
later stage.

The program to use multi-channel implants for children was
demonstrated firstly at the University of Melbourne and the Royal
Victoria Eye & Ear Hospital. Children only received an
implant after the device had firstly been shown to be effective for
prelinguistically deaf adults. It had not been shown to be effective
for prelinguistically deaf adults. The first child to receive the device
had his operation in 1984. This was a teenager who had developed
deafness from meningitis at an early age. The results were
encouraging but limited in its obtaining open-set speech recognition
was one might expect because of the relative stage of the operation in
its development.

Then it was necessary before operating on younger children to
develop a device that was smaller and that could be fitted into the
inner ear structures with less traumatic procedure, as well as
focusing on better system for attaching the external transmitter coil.
The previous device had required a headband, but in the new
water-stimulator developed by Cochlear Pty Limited in collaboration
with the University of Melbourne, there was a magnet attached to the
device that would allow the external coil with
magnet an electronics unit was worn and wired. This new device was
first fitted on a two-year-old boy at the University of Melbourne in 1986.
This child was then aged 2 and a half when he received the
implant in Melbourne in 1988. The initial results on all
these patients were encouraging and as a result a clinical trial was
undertaken by the US FDA and extended to Sydney and centres
throughout the US, as well as Germany. As a result of this clinical trial,
the results on all these patients were encouraging and as a result a clinical trial was
undertaken by the US FDA and extended to Sydney and centres
throughout the US, as well as Germany. As a result of this clinical trial,
the Water-Stimulator was firstly approved by the FDA in 1990 as
safe and effective for use in children. It was found that
approximately 50 percent of these children were able to get some
speech recognition using electrical stimulation alone as
compared with the use of a hearing aid in another group
and tactile stimuli in a third group. Results showed clearly that the Cochlear
Pty Limited multi-channel implant gave better speech
recognition, speech production and language skills than the
other aids.

Cochlear implants have now been clearly established as
providing a hearing aid in another group
and tactile stimuli in a third group. Results showed clearly that the Cochlear
Pty Limited multi-channel cochlear implant gave better speech
perception, speech production and language skills than the
other aids.

Figure 3

Of course helped severely profoundly deaf children with some
residual hearing to be aided.

Since the FDA approval, further research has been undertaken
with the implant in children, and it has been found that the
improved strategies that were developed and established on adults
were also effective in children. Most of the children were
subsequently converted over to the Multipeak strategy and more
recently a clinical trial has been undertaken at the Universities
of Melbourne and Sydney to compare the benefits of the new Spectral
Maxima Strategy with the Multipeak device. This has been part
of joint research undertaken by the Cooperative Research Centre
Ear Hospital and Hearing. This has shown that
the children can obtain significant benefits from a change in speech
processing and particularly hear better in the presence of noise.
Recently, the results of an NIH sponsored study on the Cochlear
Pty. Limited multi-channel implants, carried out at the Central
Institute of the Deaf in the US, were reported. The cochlear implant
was trialed on one matched group of children and the results were
compared with the use of a hearing aid in another group
and tactile stimuli in a third group. Results showed clearly that the Cochlear
Pty. Limited multi-channel cochlear implant gave better speech
perception, speech production and language skills than the
other aids.